AASHTO Pavement Design

By

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FAE_ZUN

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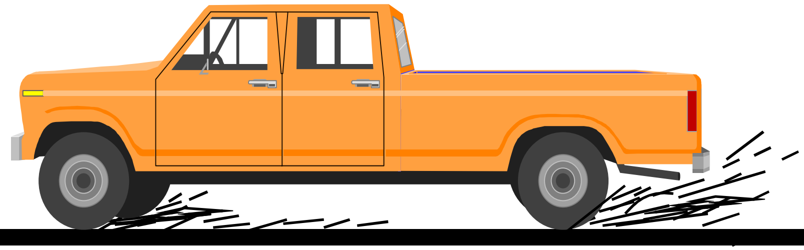
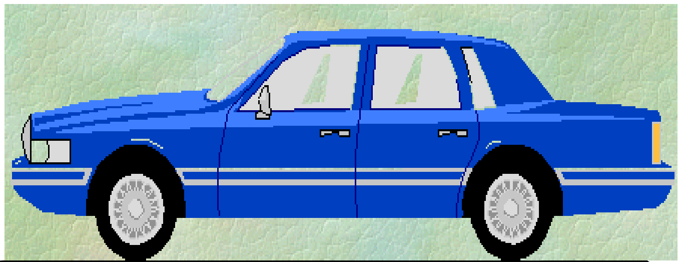
Structural Performance

Strength

Functional Performance

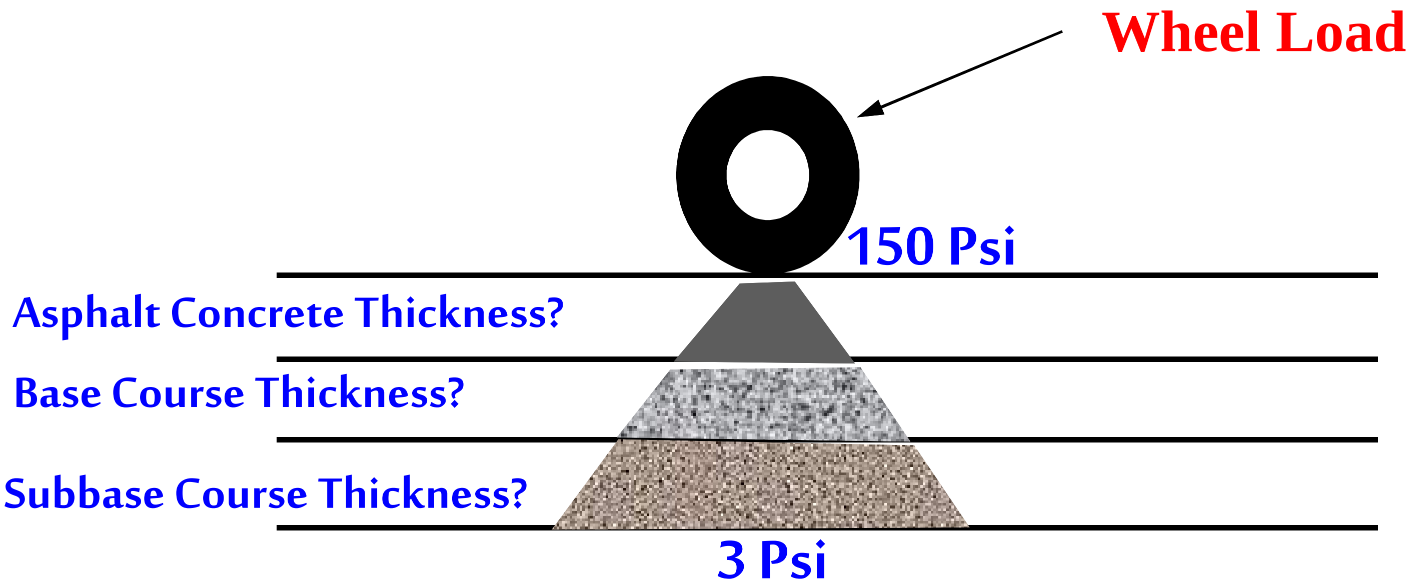


Safety



Comfort

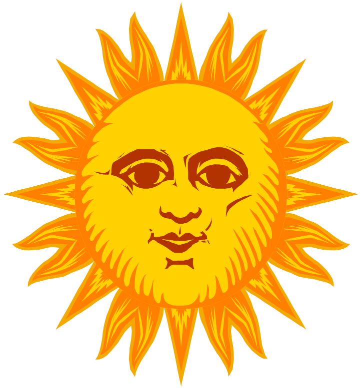
Thickness Design



Given In Situ Soil Conditions

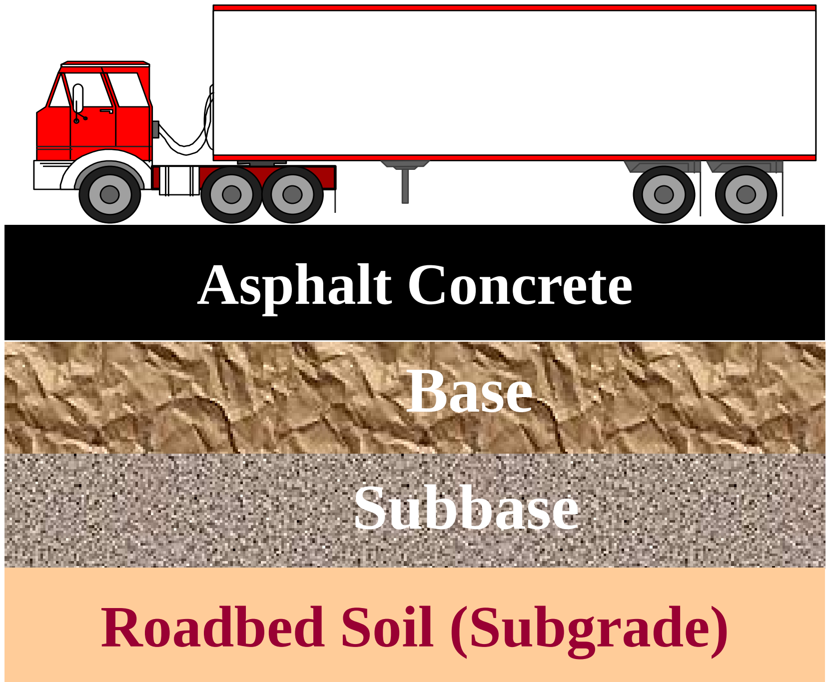
DESIGN PROCESS

Climate/Environment



Traffic Load
(Rept. , Magnet.)

Material Properties



AASHTO Design Method

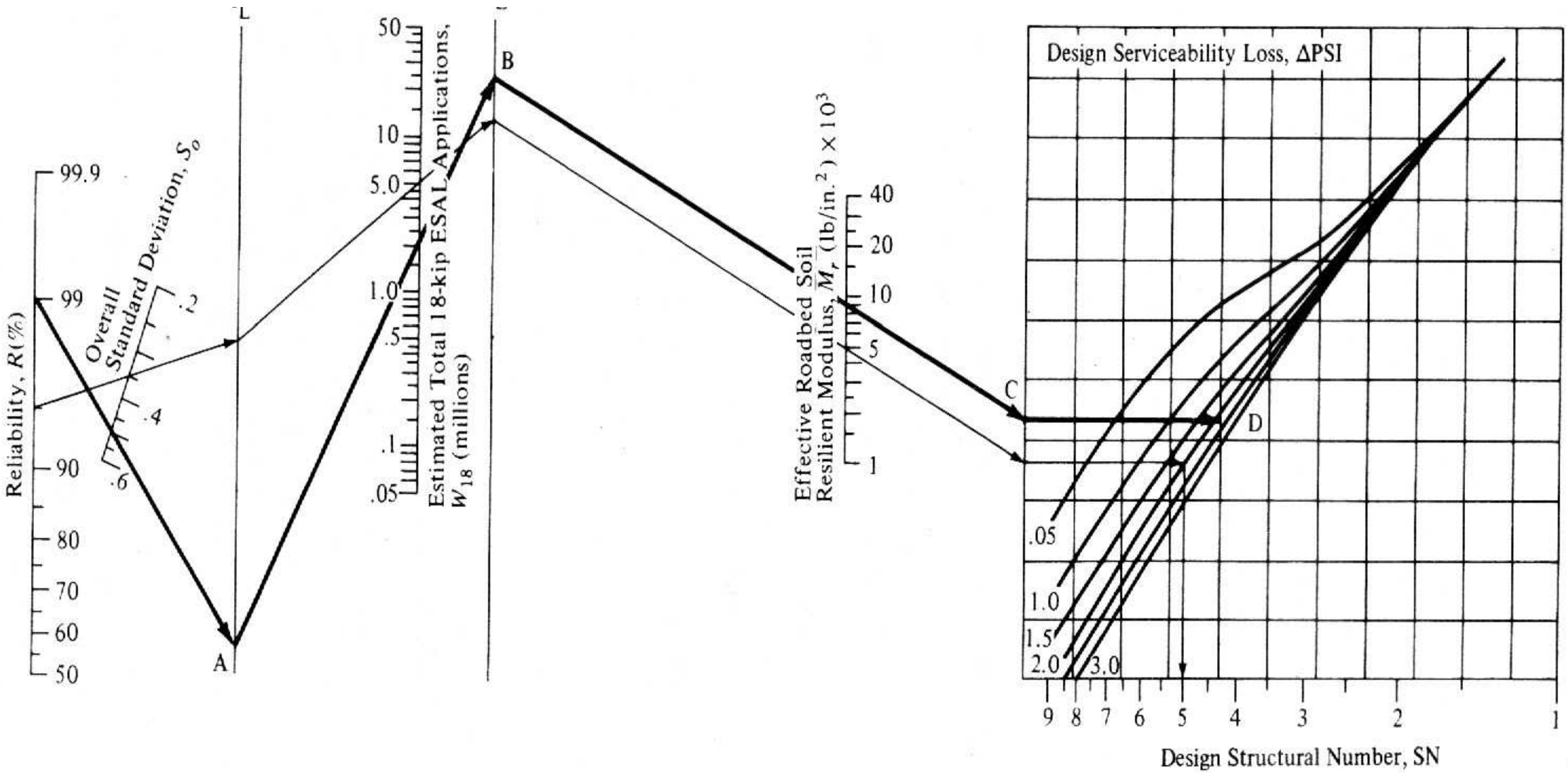
(American Association of State Highway and Transportation Officials)

DESIGN CONSIDERATIONS

- General
- AASHTO Performance
- Traffic Loads
- Roadbed Soils (Sub grade Material)
- Materials of Construction
- Environment
- Drainage
- Reliability

Structure Number (SN)

$$\text{Log}(W18) = (ZR * So) + 9.36*\text{LOG}(SN+1) - 0.2 + \text{LOG}((P2 - P1)/(4.2 - 1.5))/(0.4 + 1094/(SN+1)^{5.19}) + 2.32*\text{LOG}(MR) - 8.07$$



R S ESAL Mr ΔPSI SN

Structure Number (SN)

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

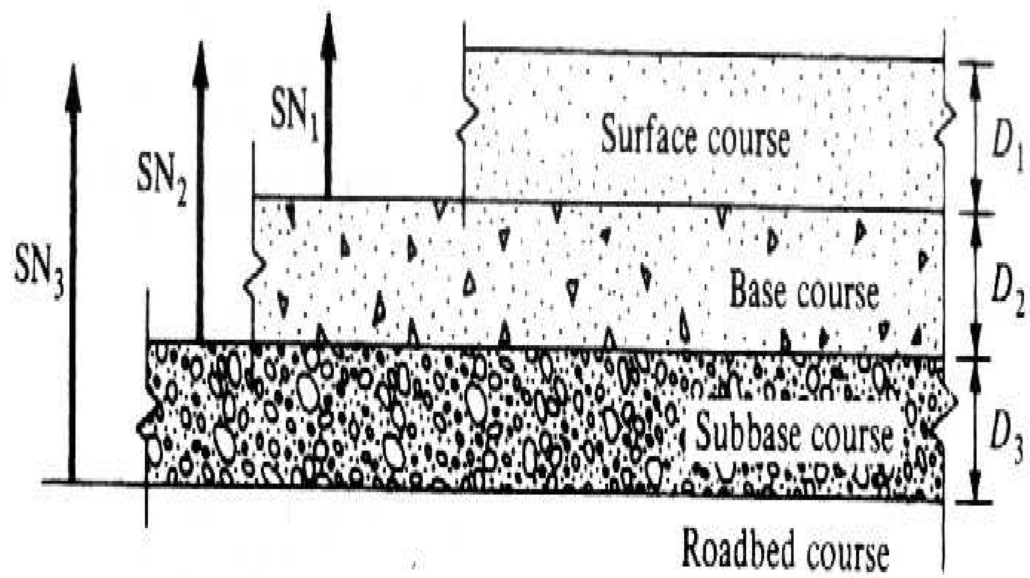
D_1, D_2, D_3 = actual thickness in inches of surface, base & sub base course

<u>**الرقم الإنشائي:**</u>هو رقم دليلي لطبقات الرصف ناتج من تحليل المرور وتربة التأسيس والمعامل البيئي ويمكن تحويل هذا الرقم إلى سمك الطبقات المختلفة للرصف المرن عن طريق استخدام معاملات الطبقات والتي تعتمد على أنواع المواد المستخدمة في طبقات الرصف المختلفة ويرمز لمعامل الطبقة برمز (a_1، a_2، a_3) لطبقات السطح والأساس والأساس المساعد بالترتيب.

$SN_1 = a_1D_1$

$SN_2 = a_1D_1 + a_2D_2m_2$

$SN_3 = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$



Reliability (R%, S_o)

- Reliability depends on highway class & Region.
- ESAL based on assume growth rate, i.e may not be accurate
  - Other method do not consider this uncertainty
  - AASHTO consider→ reliability factor→ possible uncertainties in traffic condition performance prediction
- Variation in traffic forecast
- 50 % Reliability→ design performance success is 50 %

Reliability (R%, S_o)

Suggested levels of reliability for various functional classification

	Standard Deviation , S_o
Flexible pavement	0.4-0.5
Rigid Pavement	0.3-0.4

	Recommended Level of Reliability, R%	
Functional Classification	Urban	Rural
Freeways	85-99.9	80-99.9
Arterial	80 – 99	75 – 95
Collectors	80 – 95	75 – 95
Local	50 – 80	50 – 80

Reliability (R%, S_o)

Standard Normal Deviation (Z_R) Values Corresponding to Selected Levels of Reliability

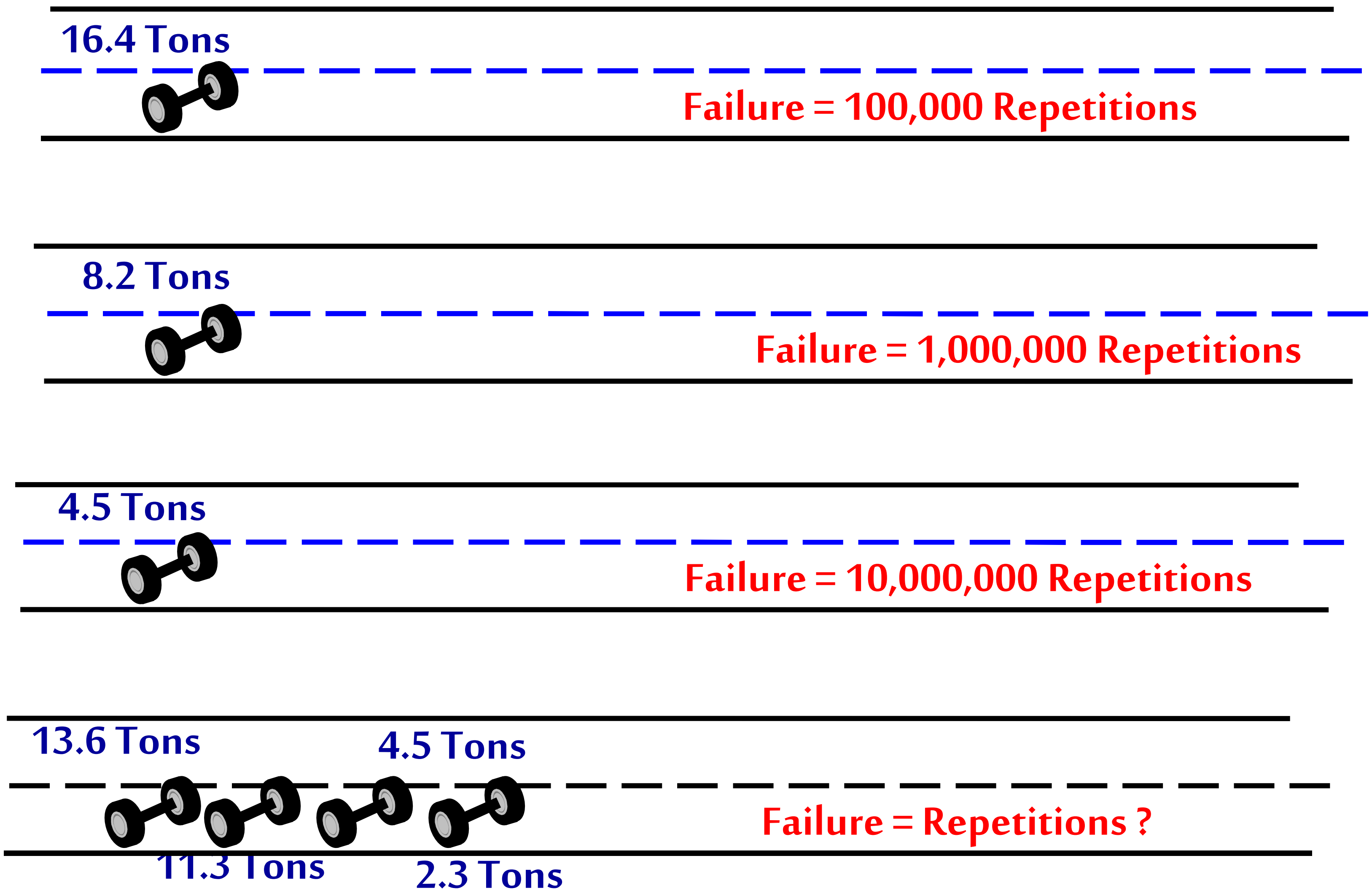
Reliability (R%)	Standard Normal Deviation ,Z_R
85	1.037
90	1.282
91	1.340
92	1.405
93	1.476
94	1.555
95	1.645
96	1.751
97	1.881
98	2.054
99	2.327
99.9	3.090
99.99	3.750

(R) هي درجة الثقة المرغوب فيها من المصمم وباقي الدرجة هو احتمال الانهيار المبكر للقطاع.

(S) هي درجة التباين الموجودة في قيم مدخلات التصميم مثل خصائص المواد و.................

ويعتمد الكود المصري لأعمال الطرق القيم التالية (R = 95%, S = 0.45)

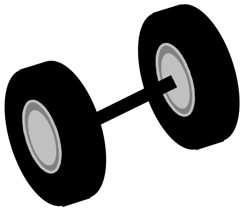
Traffic Loads (Relative Damage Concept)



Traffic Loads (Relative Damage Concept)

Equivalent
Single
Axle Load

ESAL



18000 - lbs

(8.2 tons)

Damage per
Pass = 1

Axle loads bigger than 8.2 tons cause damage greater than one per pass

Axle loads smaller than 8.2 tons cause damage less than one per pass

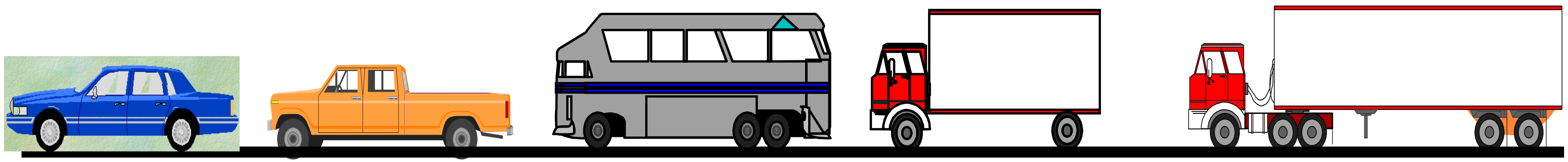
Load Equivalency Factor (L.E.F) = $(w \text{ tons}/8.2 \text{ tons})^4$

Traffic Loads (Relative Damage Concept)

In Term of : Equivalent (18000 lb or 8200 kg) Single Axial Load (ESALs)

المحور القياسي هو (١٨٠٠٠ رطل أو ٨٢٠٠ كجم) محور مفرد والمعامل المكافئ لمحور ما (LEF) يعطي نسبة التأثير لكل مرة تمر فيها مركبة على رصف معين إلى التأثير الذي يحدثه مرور الحمل القياسي على نفس الرصف. ويعبر (ESALs) عن عدد مرات تكرار الحمل الذي يؤدي إلى وصول الرصف لنهايته المقبولة بصلابة طبقة الرصف وخواص الأحمال ومستوى الخدمة

Cars **Pickups** **Buses** **Trucks** **Trailers**



Traffic Loads (LEF)

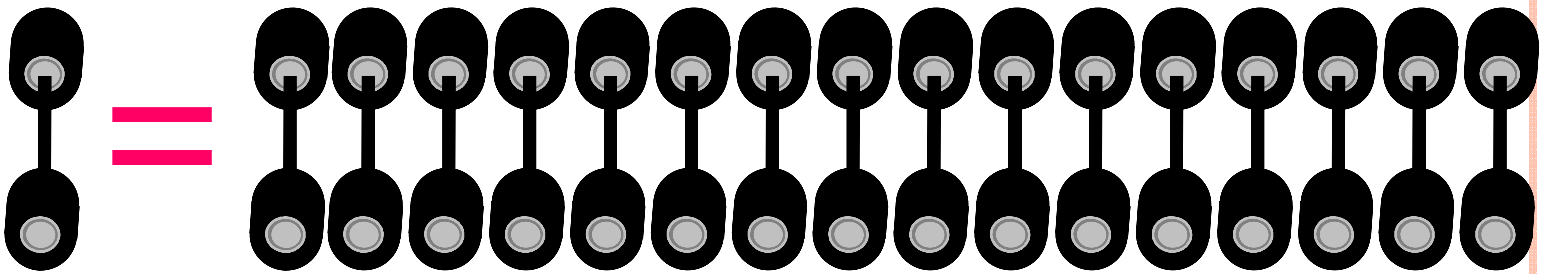
Example;

Consider two single axles A and B where:

A-Axle = 16.4 tons

Damage caused per pass by A –Axle (LEF) = $(16.4/8.2)^4$ = 16

This means that A-Axle causes same amount of damage per pass as caused by 16 passes of standard 8.2 tons axle i.e.,



16.4 Tons Axle

8.2 Tons Axle

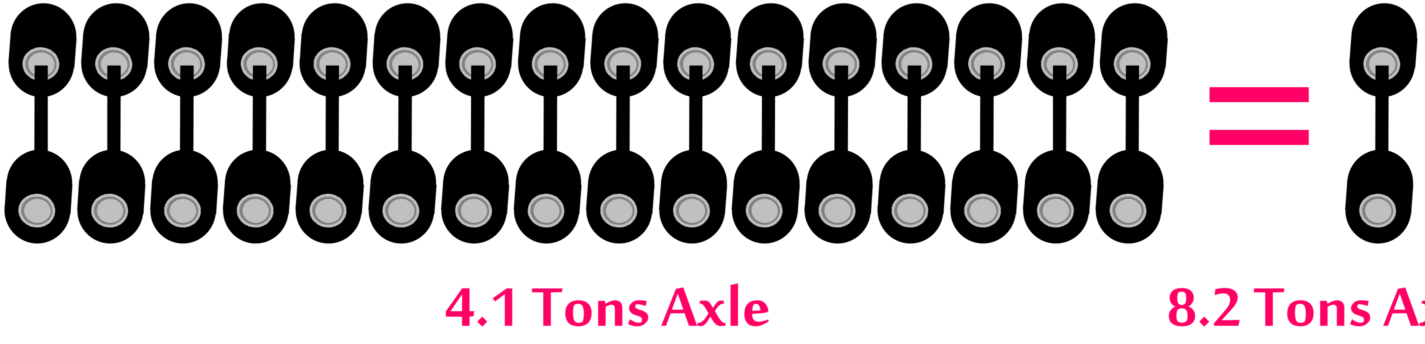
Traffic Loads (LEF)

B-Axle = 4.1 tons

Damage caused per pass by B-Axle (LEF) = $(4.1/8.2)^4$ = 0.0625

This means that B-Axle causes only 0.0625 times damage per pass as caused by 1 pass of standard 8.2 tons axle.

In other works, 16 passes (1/0.0625) of B-Axle cause same amount of damage as caused by 1 pass of standard 8.2 tons axle i.e.,



Traffic Loads (TF)

LEF, for any axle weight (w in lbs) or (w in tons)

$= (w/18{,}000)^4$...or $(w/8.2)^4$........for single axles

$= (w/33{,}400)^4$...or $(w/15.1)^4$......for tandem axles

$= (w/47{,}500)^4$...or $(w/21.8)^4$......for tridem axles

$$TF = [\sum LEF \times \text{No of Axles}]/\text{No of Trucks}$$

Traffic Loads (ESAL)

Traffic representation in AASHTO design is based on the cumulative expected 18-kip Equivalent Single Axle Load (ESAL) during the analysis period. The damage effect of a vehicle is expressed in terms of the Truck Factor (TF).

$$\mathbf{ESAL\ (W_{18}) = ADT \times T \times TF \times DD \times LD \times G \times 365}$$

ADT = Average daily traffic

T = Truck percent

TF = Truck Factor value of all trucks [$\sum$LEF × No of Axles]/No of Trucks

DD = Directional distribution factor

LD = Lane distribution factor

G = growth factor = $[(1+r)^n - 1]/r$ r is decimal rate

Traffic Loads (Example)

Calculate the TF for the given axles composition of 1000 trucks as shown in the following table

Single				Tandem			
Axle Load (kips)	LEF	**No. of axles**	LEF*Axles	**Axle Load (kips)**	LEF	**No. of axles**	LEF*Axles
24	3.16	10	31.6	44	3.01	30	90.3
22	2.23	20	44.6	40	2.06	60	123.6
20	1.52	200	304	36	1.35	100	135
18	1.0	300	300	32	0.84	400	336
Summation			680.2	Summation			684.9

LEF = $(w/18{,}000)^4$......for single axles

LEF = $(w/33{,}400)^4$......for tandem axles

TF = (680.2 + 684.9)/1000 = 1.365

Material of Construction (Mr)

Resilient modulus (M_r) of Roadbed Soils (Sub grade Material)

<u>for CBR of 10% or less</u>

$$M_r\ (lb/in^2) = 1500\ CBR$$

<u>for CBR of more than 10%</u>

$$M_r\ (lb/in^2) = 3000\ CBR$$

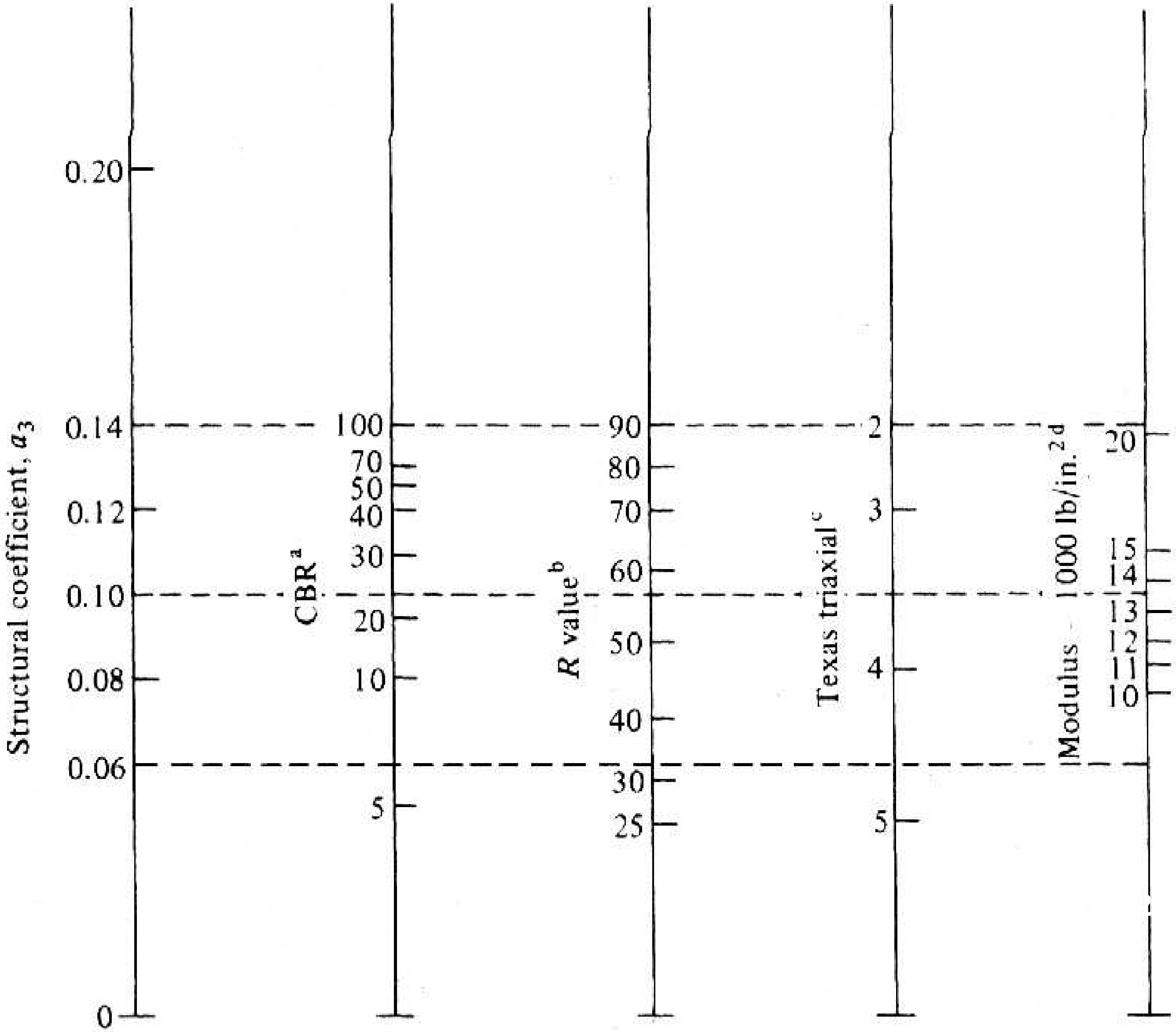
<u>for R of 20 or less</u>

$$M_r\ (lb/in^2) = 1000 + 555xR\ value$$

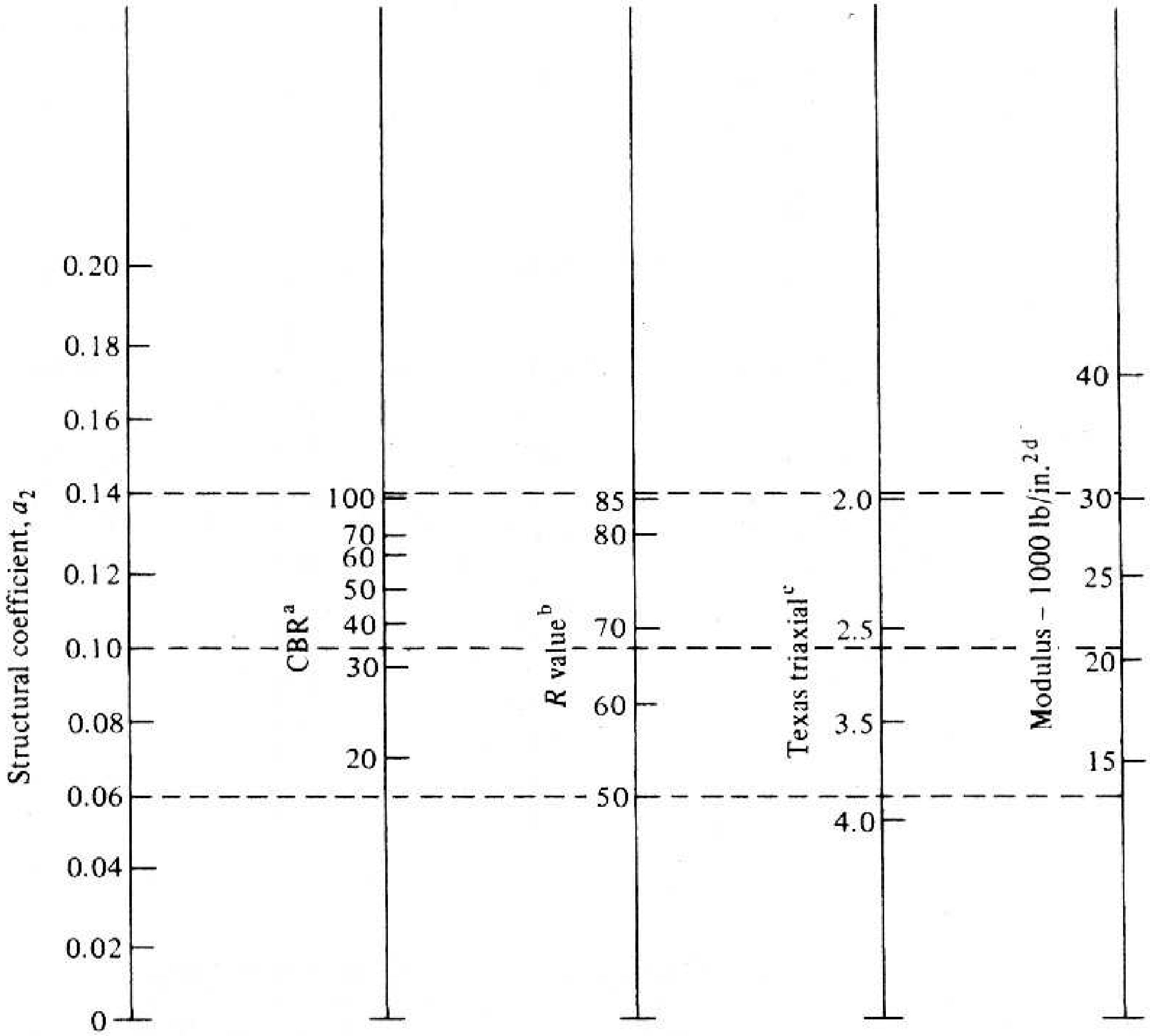
Quality of Material In terms of Layer Coefficient (a)

- Sub base Construction Material (a_3)
- Base Course Construction Material (a_2)
- Surface Course Construction Material (a_1)

Material of Construction (a_3)

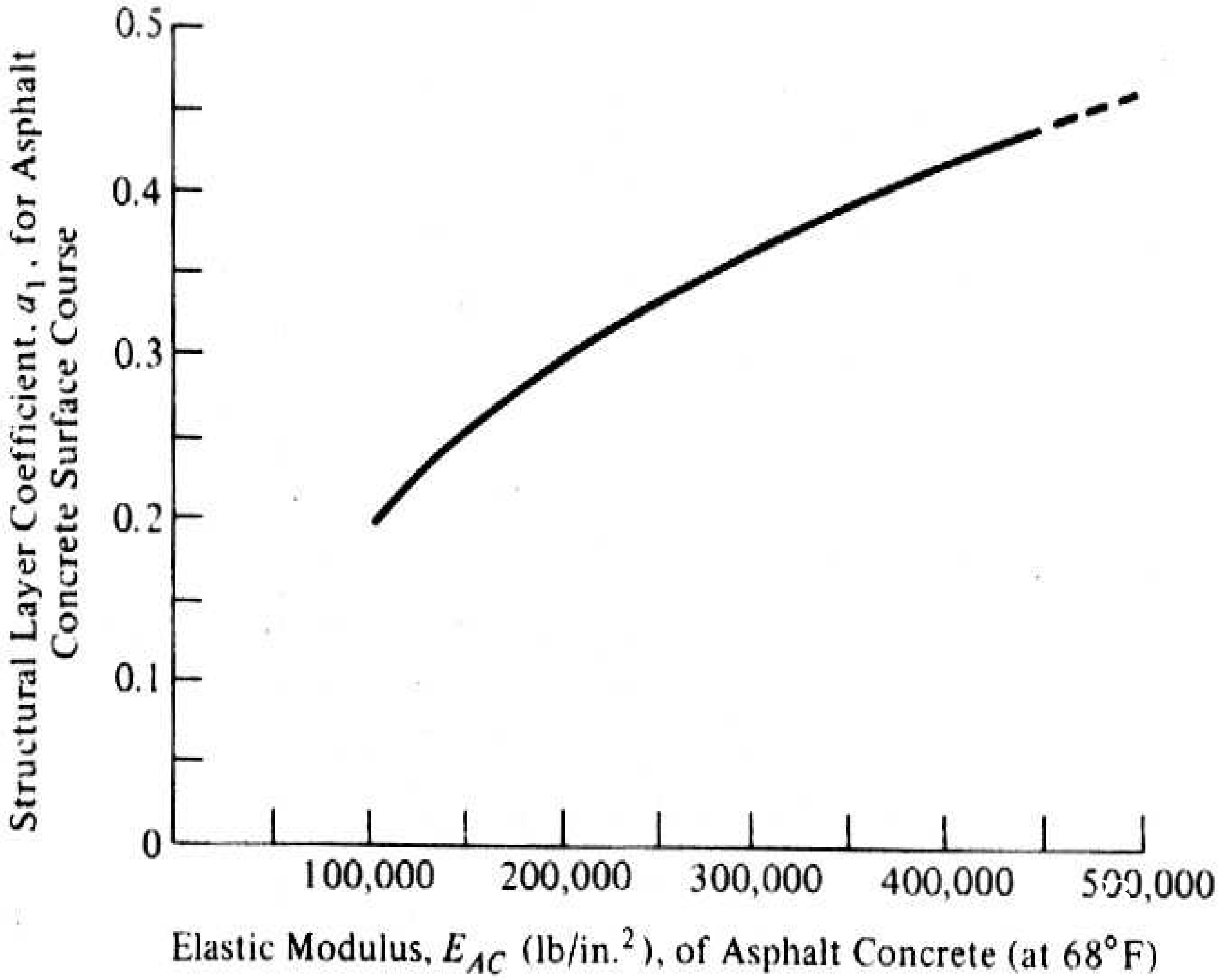


Material of Construction (a_2)



Material of Construction (a_1)

(Resilient) Modulus

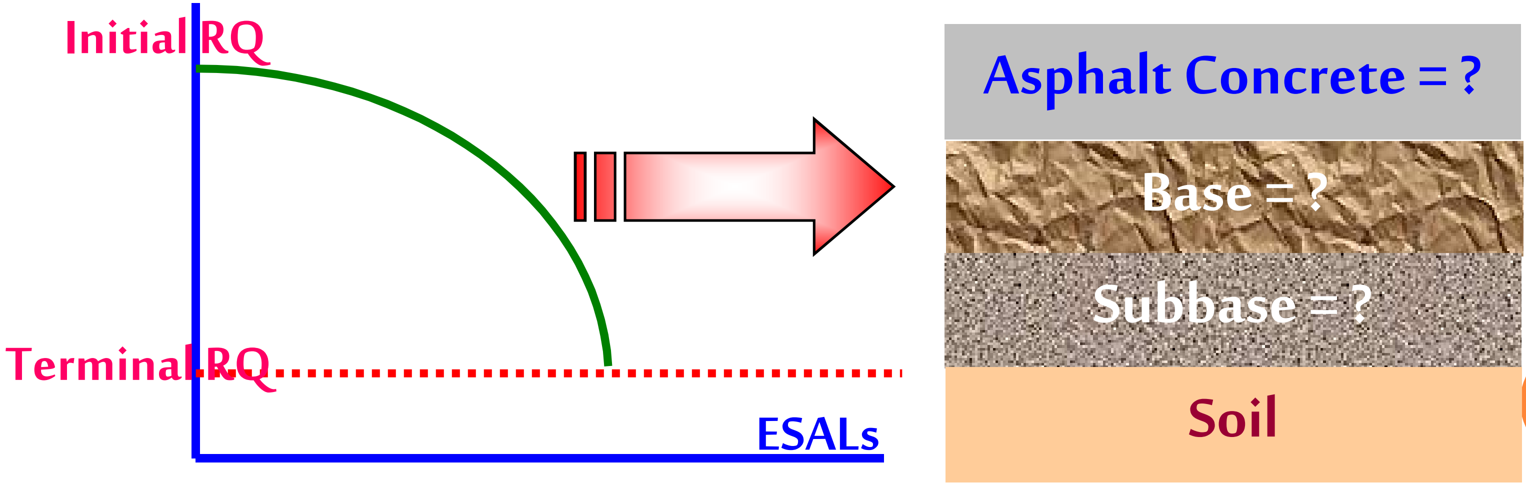


AASHO Performance

- "Test Sections" were subjected to 1.114 million applications of load.

- Performance measurements (roughness, rutting, cracking etc.) were taken at regular intervals and were used to develop statistical performance prediction models that eventually became the basis for the current AASHTO Design procedure.

- AASHTO performance model/procedure determines for a given soil condition, the thickness of Asphalt Concrete, Base Course and Subbase Course needed to sustain the predicted amount of traffic (in terms of 8.2 tons ESALs) before deteriorating to some selected level of ride quality.



AASHO Performance

Two Serviceability Indices

1. initial serviceability index (p_i)
2. terminal serviceability index (p_t)

1. **Initial serviceability index (p_i)**

- Serviceability index immediately after pavement construction.
- p_i = 4.2 based on existing condition (4.5 for good condition)

2. **Terminal serviceability index (p_t)** Based on class of highway

- P_t = 2.5 or 3 (for major highway)
- P_t = 2.0 (for lower class highway)
- P_t = 1.5 (for economic constraints performance period may be reduced)

Environment (m)

- Temperature
- Rainfall

Drainage Factor, m_i , Based on % of time during which pavement str.

Quality of Drainage	Water Removed within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	water will not drain

Recommended m_i Values

% of time pavement str. Is exposed to moisture levels approaching saturation

Quality of drainage	less than 1%	1-5%	5-25%	greater than 25%
Fair	1.25-1.15	1.15-1.05	1.0-0.8	0.80

Example

Given

- Flexible Pavement
- ESAL = 2×10^6
- Asphalt Concrete at 68°F — Modulus = 45000psi
- CBR value of base = 100, — M_r = 31000psi
- CBR value of sub base = 22, — M_r = 13500psi
- CBR of Sub grade = 6
- Reliability (R) = 99%
- Standard Deviation (So) = 0.49
- Pi = 4.5
- Pt = 2.5

Example

- ESAL = 2 x10^6
- Reliability (R) = 99%
- Standard Deviation (So) = 0.49
- PSI = 4.5-2.5 = 2.0
- a_1 = 0.44 (Modulus = 450000psi, AC)
- a_2 = 0.14 (CBR = 100,Base)
- a_3 = 0.1 (CBR = 22, sub base)
- By using AASHTO graph

  SN_3 = 4.4 (M_r= 9000 psi)

  SN_2 = 3.8 (M_r = 13500 psi)

  SN_1 = 2.6 (M_r = 31000 psi)

Example

$D_1 = SN_1/a_1 = 2.6/0.44 = 5.9''$ (use 6″)

$D_1^* = 6''$

$SN_1^* = a_1 D_1^* = 0.44 \text{ x } 6 = 2.64$

$D_2^* \geq (SN_2 - SN_1^*)/(a_2 m_2) \geq (3.8-2.64)/(0.14 \text{x} 0.8)$

$\geq 10.36''$ (Use 12″)

$SN_2^* = 0.14\text{x}0.8\text{x}12+2.64=1.34+2.64=3.98$

$D_3^* = (SN_3 - SN_2^*)/(a_3 m_3) = 4.4-(2.64+1.34)/(0.1\text{x}0.8)$

$= 5.25''$ (Use 6″)

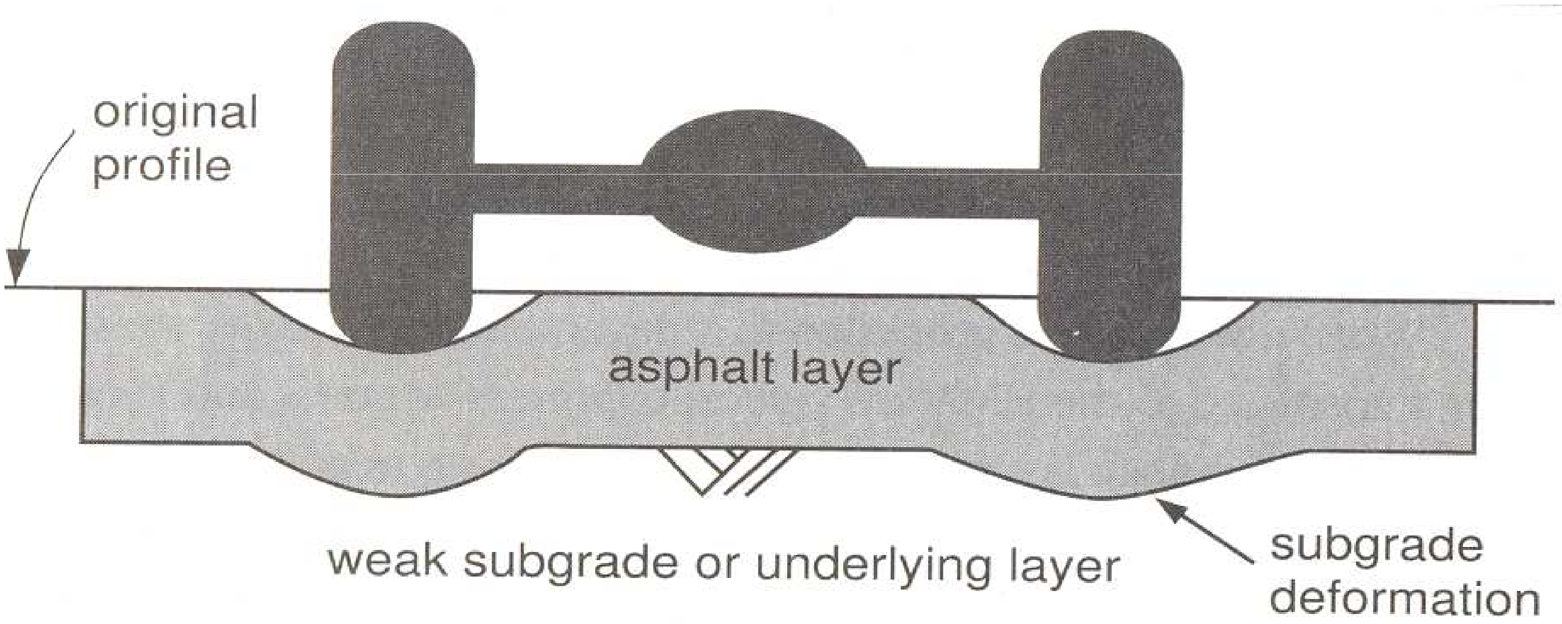
$SN_3^* = 2.64+1.34+6\text{x}0.8\text{x}0.1 = 4.46$

Asphalt concrete surface = 6″

Granular base = 12″

Sub base = 6″

Rutting in Sub-grade or Base

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